A study on the thickness of radicular dentine and cementum in anterior and premolar teeth

C. Bellucci[1] & N. Perrini[2]

[1]Private practice, Rome, Italy; and [2]Accademia Italiana Endodonzia, Pistoia, Italy

Abstract

Bellucci C, Perrini N. A study on the thickness of radicular dentine and cementum in anterior and premolar teeth. *International Endodontic Journal*, **35**, 594–606, 2002.

Aim This study aimed to measure the thickness of radicular dentine and cementum in incisors, canines and premolars, and to develop geometric average models.

Methodology The roots of 220 extracted human teeth were sectioned in three horizontal parallel planes and measured using an optical microscope. For each cut surface buccal, lingual, mesial, and distal thickness of the root wall was measured. Mean values of the thickness at each location of each cut surface were calculated. The observed differences in thickness by tooth type, location, and section were compared by ANOVA and Student's *t*-test.

Results Maxillary central incisors and maxillary canines had the greatest widths. In all teeth with a single root, the wall thicknesses were greater on the lingual side than the buccal side. Although differences between mesial and distal thicknesses were noted in all groups of teeth, they were not statistically significant.

Conclusions Wall thickness varied greatly. The lingual surfaces of roots were larger. All roots had thin walls in the apical third.

Keywords: dentine; dentinal thickness; endodontics; tooth fracture.

Received 8 August 2001; accepted 17 December 2001

Introduction

The survival of root filled teeth may depend on the amount of residual dentine (Hess & Keller 1928, Weeler 1965, Lloyd DuBrul 1980). Many studies demonstrate a direct relationship between the loss of tooth structure and the possibility of fracture of the tooth crown or root (Trabert *et al.* 1978, Guzy & Nicholls 1979, Mondelli *et al.* 1980, Sorensen & Martinoff 1984, Morfis 1990, Felton *et al.* 1991, Testori *et al.* 1993, Assif & Gorfil 1994). However, little information about the thickness of canal walls is available.

There is an appreciable loss of dentine whilst preparing the access cavity and during canal preparation. The root thickness may be thin especially where grooves are present or between two fused roots. Attention must be paid when selecting endodontic instrumentation, with regard to their diameter and flexibility so that they are compatible with the anatomic shape of the root canal.

It is generally recommended to prepare the longest possible post whilst leaving at least 4 mm of intact filling. However, although roots often appear straight in standard radiographic observations, one study reported straight roots in only 2.7% of cases (Zillich & Yaman 1986). The purpose of this study was to measure the root wall, including both dentine and cementum, in extracted human incisors, canines, and premolars to develop geometric average models. The average dimension of the radicular wall for each cut surface indicated the areas at risk of stripping, perforation and radicular fracturing during endodontic treatment and during post-preparation.

Materials and methods

A total of 220 human teeth extracted primarily for periodontal reasons from adult subjects aged between 35

Correspondence and reprint request to: Dr Cristina Bellucci, Via Nomentana – 403, 00162 Roma, Italy (fax: +39-0686217595; e-mail: crbellucci@tin.it).

and 55 years and not previously root treated were collected. The following teeth were included: 40 maxillary incisors, made up of 15 lateral incisors and 25 central incisors; 20 maxillary canines; 45 maxillary premolars; 50 mandibular incisors; 30 mandibular canines; and 35 mandibular premolars. Teeth were stored in a buffered formalin solution or a 2% sodium hypochlorite solution. The teeth were then cleaned with an ultrasonic instrument to remove calculus and placed in 2% sodium hypochlorite solution to remove remnants of the periodontal ligament. The teeth were dried and submitted for sectioning and measuring.

The buccal surface of each sample was used to measure the entire length of the tooth and the length of the root alone; all measurements were repeated. Three reference points were established and three horizontal parallel planes for sectioning the root were designated: (1) through the buccal cemento-enamel junction (2) 4 mm coronal to the anatomic apex, and (3) half-way between the other two planes. All of these measurements were made with a precision mechanical caliper, and all horizontal planes were perpendicular to the long axis of the tooth. All roots had a slight curvature, when a large curvature was present the planes were not parallel but perpendicular to the surface of the root at each position.

The teeth were sectioned by the means of an ultrathin, silicon-carbide separating disk (Dedeco International Inc., Long Eddy, NY, USA), with a thickness of 0.2 mm. Measurements of the dentinal width were made using an OPMI 1-FC optical microscope (Carl Zeiss, Oberkochen, Germany) with focal lense of 220 mm and with the aid of an object micrometer. All of the measurements were made to an accuracy of 0.01 mm. For each cut surface, the following were recorded: maximal bucco-lingual (B-L) diameter, and maximal mesio-distal (M-D) diameter; buccal root thickness, measured from the external buccal limit of the root canal to the buccal surface of the root; lingual root thickness, measured from the external lingual limit of the root canal to the lingual surface of the root; mesial root thickness, measured from the external mesial limit of the root canal to the mesial surface of the root; and distal root thickness, measured from the external distal limit of the root canal to the distal surface of the root.

No distinction was made between mandibular central or lateral incisors. All mandibular premolars were included in a single group. The presence of two canals in one root was rare. In these cases, analysis was carried out in the following manner: the buccal wall measurement was made in relation to the buccal root canal and the measurement of the thickness of lingual wall was made in relation to the lingual root canal; in the mesial and distal zones, respectively, two measurements were made corresponding to the two canals. Therefore, for sections with two canals there were six measurements of wall thickness rather than four; an arithmetic average was made between the two mesial measurements and two distal measurements. For this reason, only one canal roots appear in the graphic model. Maxillary premolars were placed in two groups depending whether they had one single root or two distinct roots.

The data obtained were processed using SPSS software (Statistical Package for the Social Sciences). Means and standard deviations of wall thicknesses were calculated for each position (buccal, lingual, mesial, and distal), each cut surface and each group of teeth. A Matlab software graphic tool (The Mathworks, Natick, MA, USA) was used to obtain the representation of the average thicknesses. Effects, and interactions of tooth type (mandibular or maxillary incisor, canine or premolar), location (buccal, lingual, mesial or distal), and section (surfaces 1–3) on the variation of wall thickness were examined by subjecting the data to a three-way analysis of variance (ANOVA). For the statistical analysis, we considered the thickness as the dependent variable and the tooth type, section and location as independent variables. A mixed, three-way ANOVA model was applied to analyze one single independent factor (tooth type) and two repeated factors (section and location). We considered all the differences tested as significant when the experimental F had a significance equal to $P < 0.05$. From this analysis, the group of maxillary premolars with two roots was excluded since it was not homogeneous with respect to the other groups of teeth. A separate analysis was conducted for this group. Moreover data were subjected to one-way ANOVA to determine which group of teeth presented the greatest wall thickness and whether the difference was significant with respect to the other groups, the Duncan post hoc test was performed with significance level of 0.01. Furthermore, the wall thicknesses were compared, to determine whether the canals were central; the means of the buccal and lingual thicknesses, and the mesial and distal thicknesses for each of the three cut surfaces were subjected to paired t-test. The test was considered statistically significant if the two-tailed significance level was less than 0.01.

Results

Sections of the roots of the maxillary central incisors were mainly circular in shape or slightly triangular; this

shape was generally maintained in the middle third of the root. The roots of the maxillary lateral incisors were flattened lengthwise in the mesio-distal direction and the radicular canal was slightly oval in shape. The sections of the maxillary canines displayed roots with a bucco-lingual major diameter; the radicular canals were oval in shape. Most of the roots of the maxillary premolars were flattened in the mesio-distal direction with a deep sulcus along the root. The maxillary premolars with two roots showed only one large chamber canal in the first section in correspondence with the cemento-enamel junction, the two roots in the remaining part were circular. The roots of the mandibular incisors were thin and flattened lengthwise in the mesio-distal direction and the radicular canals were ribbon-like. The roots of the mandibular canines were oval-shaped and the radicular canals were circular. The roots and canals of the mandibular premolars were mostly circular in shape.

The average and standard deviation of the values obtained for each group of teeth are listed in Tables 1–3. The average thicknesses of the radicular wall for each group of teeth are graphically illustrated in Figs 1–8. With the assumption that the centre of the canal is the centre of each drawing, profiles of the sections are drawn into a grid of known dimensions with values expressed in millimetres. The actual measurements are superimposed on one another for each of the three horizontal sections and displayed on the left side of the figures. In the right column of the figures, a schematic representation of the mean values of the measurements for each of the three sections is illustrated. The graphic images represent the average of the measurements obtained.

In the three-way ANOVA analysis the values of ETAsqd were calculated. ETAsqd is a statistical index that offers the indication of the size of an effect. The value of ETAsqd shows the capacity, expressed in percentages, that has a factor (tooth type, section and location, or a combination of them) to explain the variability in the dependent variable (thickness). Within the significant effects of each of the analyses, one must always be conscious of the magnitude of the effects, i.e. only those effects that may explain a good percentage of the variance should be attempted to be interpreted and emphasized. The ETAsqd indicates that despite the fact that the effects and the interaction of tooth type, section and location on wall thickness were all significant ($P < 0.05$), major importance must be attributed to the location, followed by the section, and minor importance to the tooth type and interaction of the variables.

Table 1 Mean thickness and standard deviation (±SD), in millimetres, for each cut surface of upper and lower incisors

	Maxillary central incisors						Maxillary lateral incisors						Mandibular incisors					
	Surface 1		Surface 2		Surface 3		Surface 1		Surface 2		Surface 3		Surface 1		Surface 2		Surface 3	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
B	2.3623	±0.2367	2.1804	±0.2159	1.4500	±0.2451	2.1793	±0.2714	2.1447	±0.1664	1.4727	±0.1869	2.0367	±0.2717	1.9090	±0.2662	1.5450	±0.1777
L	3.0567	±0.3852	2.4700	±0.3249	1.6688	±0.3586	2.5964	±0.2978	2.2413	±0.1972	1.7107	±0.1966	2.2590	±0.2569	1.9090	±0.2554	1.5716	±0.2322
M	2.1459	±0.2821	2.0444	±0.2503	1.2596	±0.2233	1.6671	±0.2133	1.4753	±0.0998	0.9607	±0.1488	1.4306	±0.2044	1.1352	±0.1509	0.8050	±0.2456
D	2.2927	±0.2683	2.0860	±0.2496	1.2862	±0.2824	1.8436	±0.2314	1.6320	±0.1167	0.9147	±0.1399	1.3851	±0.1922	1.1252	±0.1297	0.7698	±0.2464

B, buccal; L, lingual; M, mesial; D, distal.

Table 2 Mean thickness and standard deviation (±SD), in millimetres, for each cut surface of upper canines and lower canines and premolars

	Maxillary canines						Mandibular canines						Mandibular premolars					
	Surface 1		Surface 2		Surface 3		Surface 1		Surface 2		Surface 3		Surface 1		Surface 2		Surface 3	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
B	2.5760	±0.3587	2.5500	±0.2595	1.6890	±0.3334	2.2759	±0.3316	2.1437	±0.3273	1.4936	±0.2644	2.1740	±0.3010	2.1014	±0.3235	1.5735	±0.2659
L	2.6040	±0.5169	2.7330	±0.4050	1.8155	±0.3938	2.3490	±0.2486	2.2133	±0.3819	1.6257	±0.3083	2.2065	±0.4528	2.3034	±0.4210	1.6421	±0.3234
M	2.0165	±0.2208	1.5265	±0.2938	1.1370	±0.2448	1.6024	±0.3907	1.3053	±0.2176	1.0132	±0.1611	1.8229	±0.3374	1.4026	±0.2693	1.0941	±0.2417
D	2.1460	±0.3999	1.4470	±0.3274	1.0985	±0.2147	1.6045	±0.4896	1.3090	±0.2516	0.9339	±0.2438	1.8594	±0.2588	1.3377	±0.2531	1.0497	±0.2055

B, buccal; L, lingual; M, mesial; D, distal.

Table 3 Mean thickness and standard deviation (±SD), in millimetres, for each cut surface of upper premolars. In correspondence, the cementoenamel junction of premolars with two roots, surface 1, the two canals are still fused together

	Maxillary premolars with single canals or two canals in only one root						Maxillary premolars with two roots and two canals									
	Surface 1		Surface 2		Surface 3		Surface 1		Surface 2				Surface 3			
									Vestibular root		Lingual root		Vestibular root		Lingual root	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
B	2.0150	±0.2018	1.8765	±0.3917	1.3615	±0.3806	1.8056	±0.2546	1.4590	±0.1611	1.3970	±0.0948	1.1250	±0.3036	1.1120	±0.2413
L	2.1468	±0.3528	1.9074	±0.3463	1.4391	±0.5247	1.9278	±0.1118	1.3170	±0.1169	1.5480	±0.1940	0.9780	±0.1726	1.0890	±0.2267
M	1.5397	±0.3439	1.2150	±0.2897	0.9162	±0.3651	1.6589	±0.2601	1.4020	±0.1643	1.3730	±0.1918	0.9550	±0.2087	0.9660	±0.1794
D	1.6282	±0.4736	1.2603	±0.3128	0.9462	±0.4115	1.7144	±0.2791	1.4500	±0.1511	1.4810	±0.2355	1.0050	±0.2982	0.9900	±0.2069

B, buccal; L, lingual; M, mesial; D, distal.

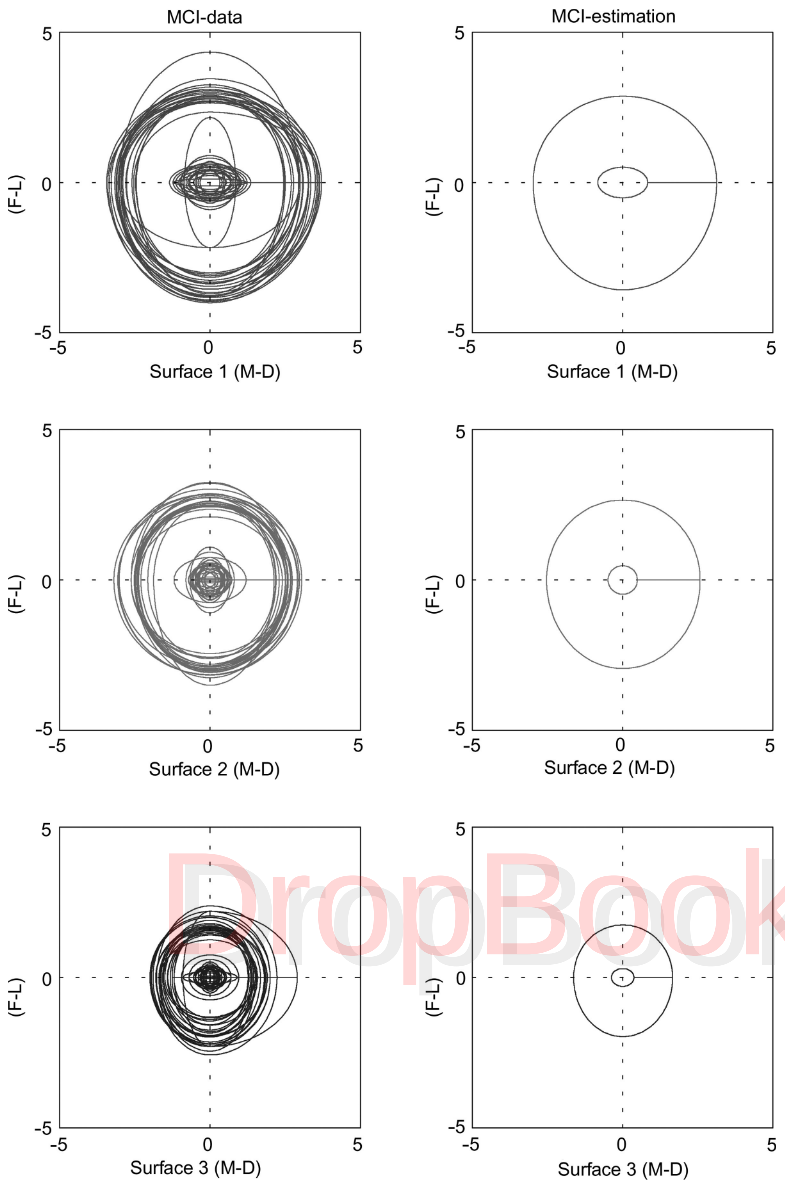

Figure 1 Maxillary central incisors (MCI): on the left is a superimposition of the graphic representation of actual measurements of all samples of the three horizontal sections. On the right is the average shape with the average wall thickness in millimetres.

In the one-way ANOVA results, the post hoc analysis with the Duncan tests, revealed that the mean wall thickness in the buccal position of the first cut surface (surface 1) was greater for maxillary canines in comparison to all the other groups of teeth; this difference is statistically significant ($P = 0.000$). The mean wall thickness in the buccal position of the second cut surface (surface 2) was also greatest for maxillary canines in comparison to all the other groups of teeth; this difference is statistically significant with respect to all groups ($P = 0.000$). Once again, the mean wall thickness in the buccal position of the third cut section, i.e. at 4 mm from the anatomic apex (surface 3), was greater for maxillary canines; this difference was statistically significant except for the group of maxillary premolars with one single root and the group of mandibular incisors ($P = 0.052$).

The mean thickness in the lingual position of the first cut surface (surface 1) was greater for maxillary central incisors; this difference was statistically significant

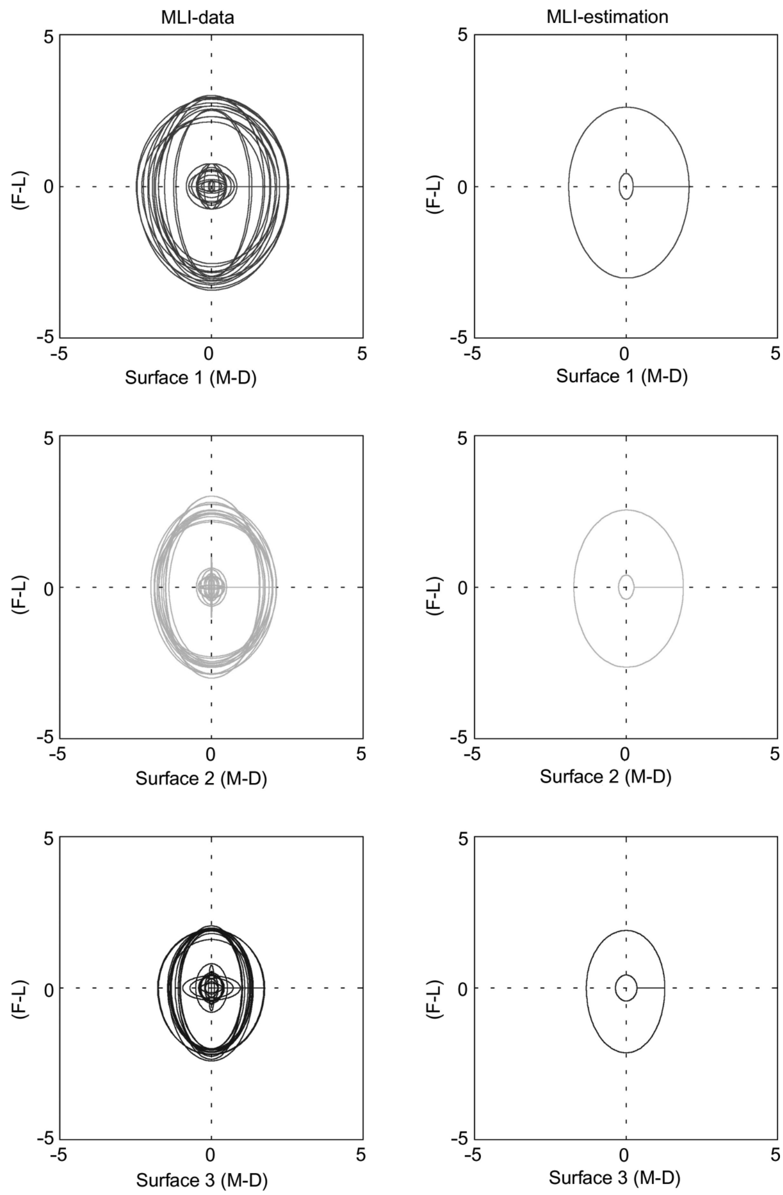

Figure 2 With the same assumption, the figure shows wall thicknesses for Maxillary Lateral Incisors (MLI).

($P = 0.008$) in comparison to all other groups. The wall lingual thickness in the second cut surface (surface 2) was greater for maxillary canines, and that was statistically significant ($P = 0.010$) in comparison to all other groups. In the third section (surface 3), the lingual thickness was greater for maxillary canines, but the difference was only statistically significant in comparison to mandibular incisors.

The mean wall thickness in the mesial position of the first cut surface (surface 1) was greater for maxillary central incisors; this difference was statistically significant except for maxillary canines ($P = 0.061$). Also, in the second cut surface (surface 2) the Duncan test revealed a greater wall thickness for maxillary central incisors. In the third cut surface (surface 3), the maxillary central incisors had a greater thickness value, but this difference was not significant in comparison to maxillary canines ($P = 0.053$).

The mean wall thickness in the distal position of the first cut surface (surface 1) was greater for maxillary central incisors; this difference was statistically significant ($P < 0.05$) except for maxillary canines ($P = 0.59$). The

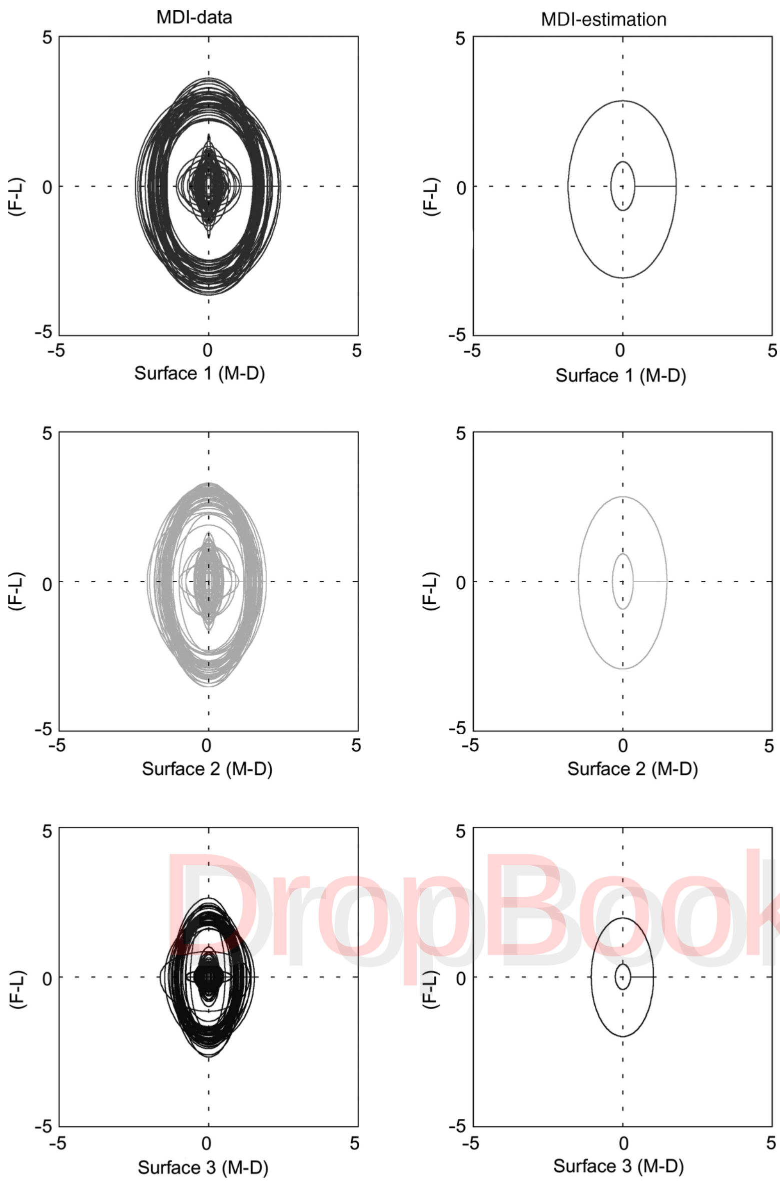

Figure 3 Wall thickness for Mandibular incisors (MDI).

distal wall thickness in the second cut surface (surface 2) was greater for the same group, and the difference was statistically significant ($P < 0.05$) with respect to all other groups. The mean distal thickness in the third cut surface (surface 3) was once again greater for maxillary central incisors; the difference was statistically significant except in comparison to maxillary canines ($P = 0.062$).

The results of the Student's *t*-test for paired samples show, for all groups of teeth, except maxillary premolars with two roots, and in all sections, that the wall thicknesses are greater on the lingual side than the buccal side. The Student's *t*-test revealed that this difference was statistically significant ($P < 0.01$) with the exception of: maxillary canines, mandibular canines, maxillary premolars with only one root, and mandibular premolars in the first section; mandibular canines and maxillary premolars with only one root in the second section; mandibular incisors, maxillary canines, maxillary premolars with only one root, mandibular canines, and mandibular premolars in the third section.

The differences between the mesial and distal thicknesses for all groups and for all sections were also compared. Although in many sections, the distal or mesial

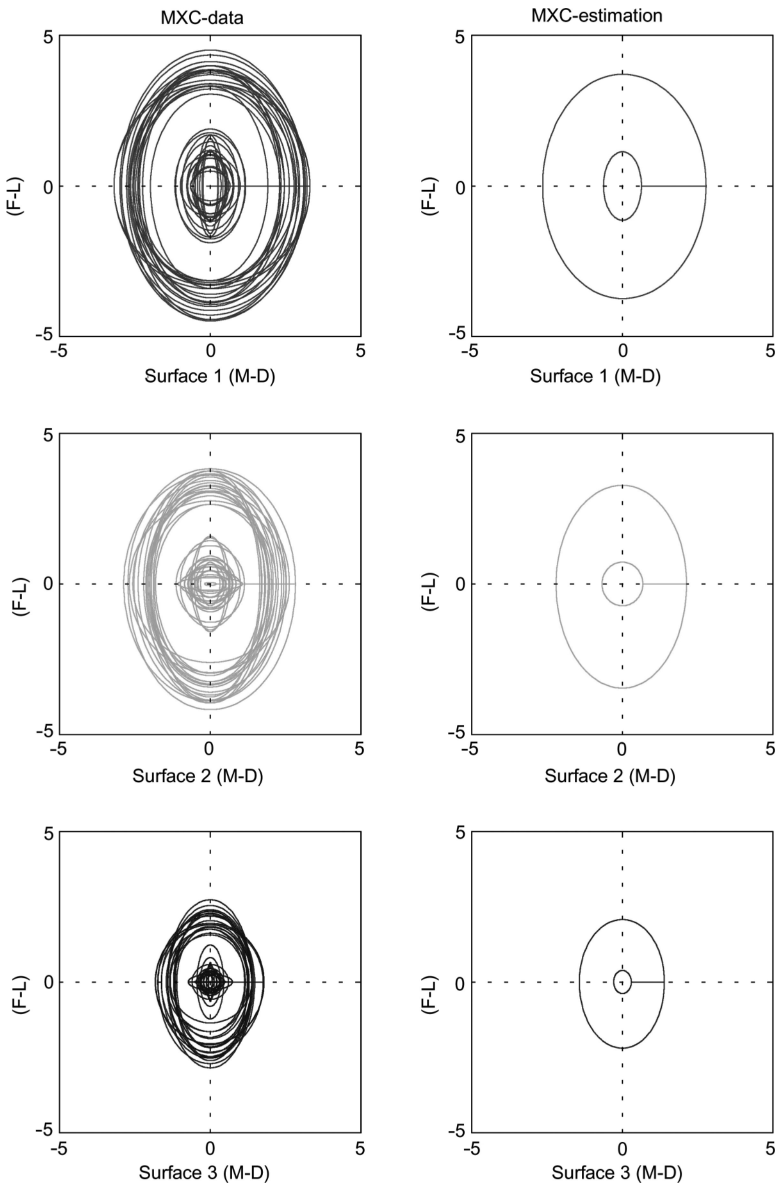

Figure 4 Wall thickness for Maxillary canines (MXC).

widths were greater, the analysis revealed that the differences were never statistically significant ($P > 0.01$) except the second sections of maxillary lateral incisors ($P = 0.003$).

As mentioned above, the statistical analyses for maxillary premolars with two roots were performed separately, i.e. eight rather than four thickness variables. For this group of teeth, in the second section, the buccal thickness of the buccal root was greater than the lingual thickness, and the lingual thickness of the lingual root was greater than the buccal thickness; these differences were statistically significant ($P < 0.05$).

Also in the second section, the distal widths are greater than the mesial widths in both the roots. These differences are also statistically significant ($P < 0.05$).

Discussion

There is little information in the literature concerning the thickness of radicular dentine. This study was

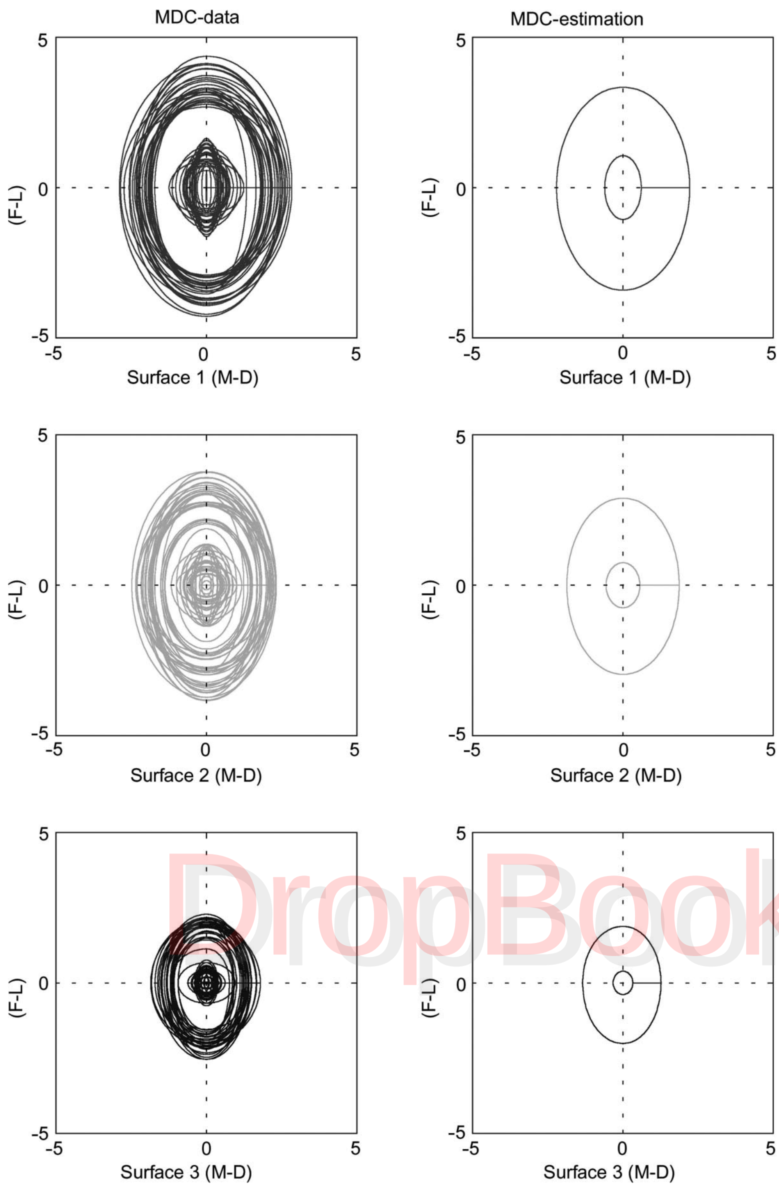

Figure 5 Wall thickness for Mandibular canines (MDC).

carried out with the intention of providing important data on this relevant topic.

The pulp of a tooth decreases in volume with the passage of time. The teeth examined in this study were from adult subjects aged between 35 and 55 years. The teeth were extracted primarily because of periodontal disease and the canals were often narrow.

Amongst the specimens examined the presence of two canals in a single root was rare. Only one main canal was found in each of the 40 maxillary incisors examined. In the group of maxillary canines only one specimen was divided in the coronal third due to the presence of a dentinal island. No distinction was made between mandibular central or lateral incisors because there were no remarkable differences between the two groups. Sometimes dentine islands forming two canals were noted in the second and third sections within a longitudinally flattened canal, however, the canals always had a single apical foramen. For the group of mandibular canines, only in one case out of the 30 teeth examined

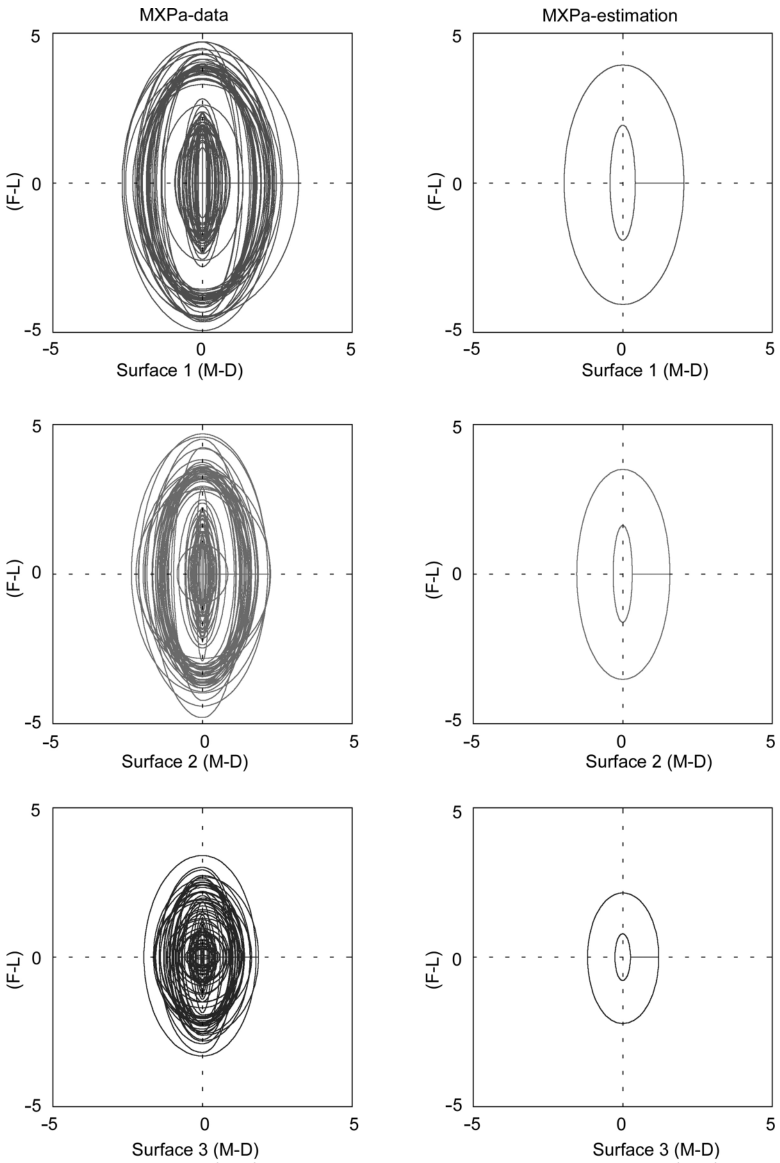

Figure 6 Wall thickness for Maxillary premolars with single canals or two canals in only one root (MXP[a]).

were there two roots and two canals, in all the other cases there was one single, generally wide, canal. All mandibular premolars were included in a single group because none were found with two canals and also because roots of first and second premolars were similar in shape.

The results of the ANOVA, with the computation of the ETAsqd, show that the thickness of radicular dentine mainly varies depending on location and section factors rather than tooth type. In other words, independent of the tooth type, a similar variation of dentine thickness can be observed in all of the teeth studied.

Larger values of dentine thickness were detected near the lingual and buccal surfaces with reduced thicknesses near the mesial and distal surfaces. In many sections, the dentine was very thin. Thus, it follows that the knowledge of the radicular dentine thickness must serve as a guide to all treatment that includes the root of the tooth. Clearly, one must use the utmost caution when introducing rotating, rigid or large-diameter instruments into the canal.

Biomechanical studies suggest that at least 1 mm of root dentine should remain around the post (Caputo &

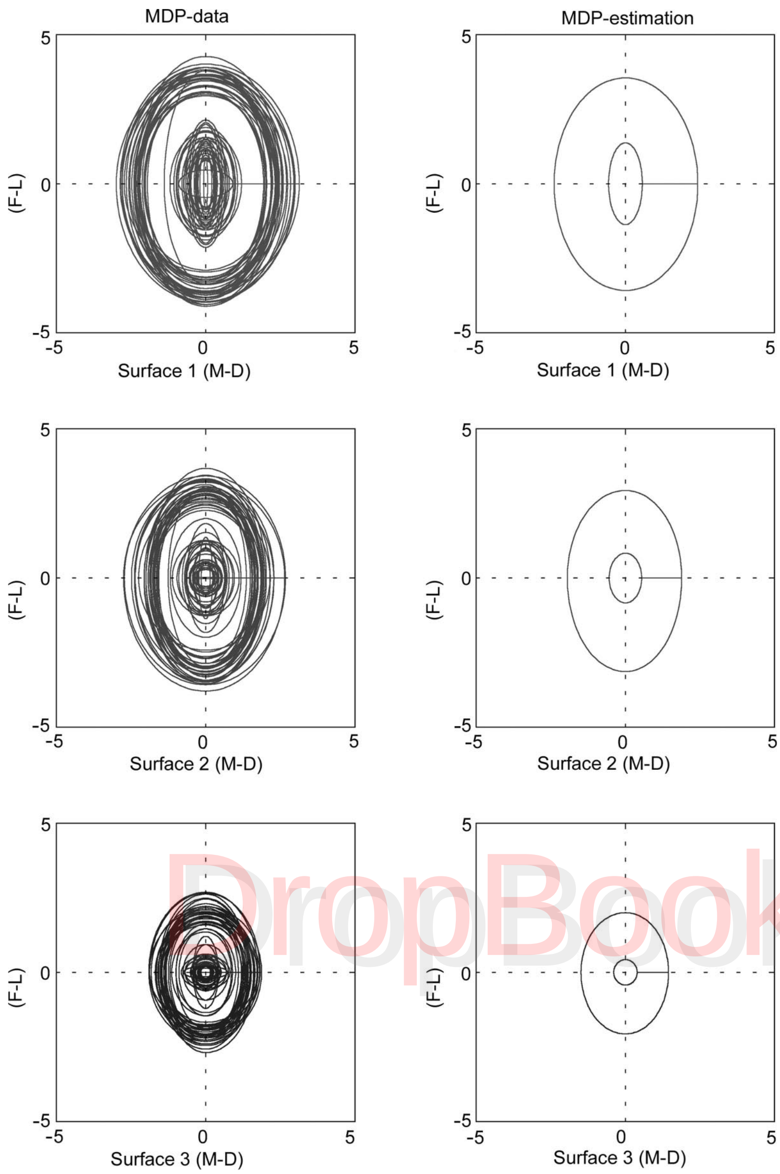

Figure 7 Wall thickness for Mandibular premolars (MDP).

Standlee 1988) to avoid the risk of root fracture. Therefore, during canal preparation it is advisable to remove as little dentine as possible and during post-preparation, it is advisable to follow the anatomy of the radicular canal by designing flattened posts in a mesio-distal direction, with tapered vertical walls. The dentine should mainly be removed, if necessary, in the lingual area where the thickness is greater. In the apical part, there is very little dentine available therefore in this area it is preferable not to remove any dentine but only to clean the canals of filling material.

This study has been limited to the observation of radicular dentine thickness in anterior teeth and premolars. The teeth examined belonged to adult subjects between the ages of 35 and 55 years that were extracted because of periodontal disease.

As a result, data on the dentine thickness of teeth from younger subjects is missing. This would be expected to show a smaller radicular dentine thickness due to larger dimensions of the pulp. In the future it would be desirable to conduct studies on posterior teeth and other age groups.

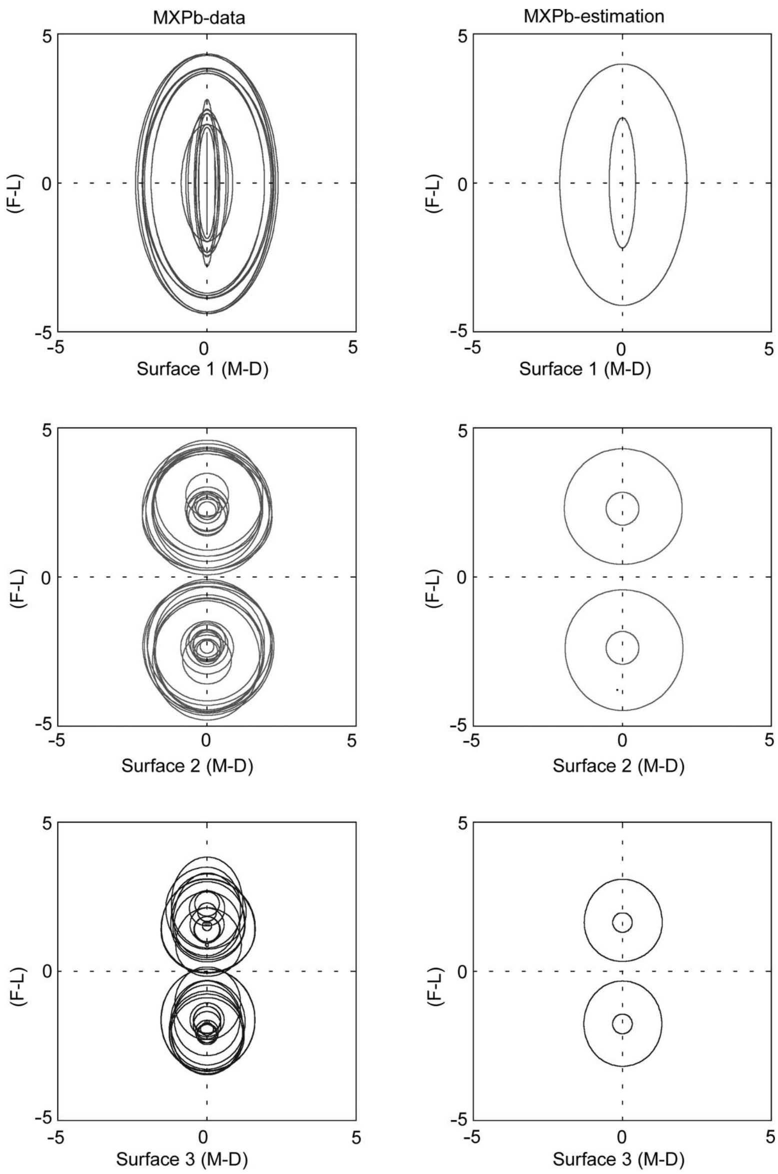

Figure 8 Wall thickness for Maxillary premolars with two canals and two roots (MXP^b).

Conclusions

The aim of the study was to calculate an average thickness of root dentine and cementum for anterior and premolar teeth. The results obtained and the analysis conducted allowed the formulation of a hypothesis of a 'standard average' form for each group of teeth. Based on the results of this study, the following conclusions were drawn:

1 Wall thicknesses varied greatly.

2 Generally, thicknesses were greater on the lingual surfaces of the roots.

3 Statistically significant differences between thicknesses in the mesial and distal surfaces of the roots were observed only in one case. Nevertheless, many roots were flattened mesio-distally.

4 Wall thickness was thin in the apical third.

Acknowledgements

We would like to express particular thanks to Mr Fabrizio Impagnatiello, Eng, and to Mrs Gabriella Candilera and Mr Paolo Iliceto, for their technical support.

References

Assif D, Gorfil C (1994) Biomechanical considerations in restoring endodontically treated teeth. *Journal of Prosthetic Dentistry* **71**, 565–7.

Caputo AA, Standlee JP (1988) Basic principles of posts: a foundation for the future. *Journal of Clinical Dentistry* **1**, 45–9.

Felton DA, Webb EL, Kanoy MA, Dugoni J (1991) Threaded endodontic posts: effects of their morphology on the incidence of radicular fractures. *Journal of Prosthetic Dentistry* **65**, 179–84.

Guzy GE, Nicholls JI (1979) In vitro comparison of intact endodontically treated teeth with and without endopost-reinforcement. *Journal of Prosthetic Dentistry* **42**, 39–42.

Hess W, Keller O (1928) *Anatomical Plates*. Zurich, CH: University of Zurich.

Lloyd DuBrul E (1980) *Sicher's Oral Anathomy*, 1st edn. St. Louis, MO, USA: C.V. Mosby Company.

Mondelli J, Steagal IL, Ishikiriama A, Navarro M, Soares FB (1980) Fracture strength of human teeth with cavity preparation. *Journal of Prosthetic Dentistry* **43**, 419–22.

Morfis AS (1990) Vertical root fractures. *Oral Surgery, Oral Medicine and Oral Pathology* **69**, 631–5.

Sorensen JA, Martinoff MD (1984) Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. *Journal of Prosthetic Dentistry* **51**, 780–7.

Testori T, Badino M, Castagnola M (1993) Vertical root fractures in endodontically treated teeth: a clinical survey of 36 cases. *Journal of Endodontics* **19**, 87–90.

Trabert K, Caputo AA, Abou-Rass M (1978) Tooth fracture: a comparison of endodontic and restorative treatments. *Journal of Endodontics* **4**, 341–4.

Weeler RC (1965) *A Textbook of Dental Anatomy and Physiology*, 4th edn. Philadelphia, USA: W.B. Saunders Company.

Zillich R, Yaman P (1986) Root curvature localizations as indicators of post-length in various tooth groups. *Endodontics and Dental Traumatology* **2**, 58–61.

